Marine Physical Laboratory

Adaptive Beach Monitoring

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The long-term goal of the Marine Physical Laboratory's Adaptive Beach Monitoring (ABM) program is to determine the capabilities of small on-shore and off-shore seismoacoustic arrays along with directional wave and current sensors to provide the amphibious force commander with a covert monitoring capability of shore-based as well as near-shore enemy forces, near-shore current and wave dynamics, and beach surf conditions.

The science objectives of the ABM program are to understand the source mechanisms of naturally occurring (e.g., breaking surf and biological) and manmade (e.g., land vehicle) seismoacoustic sounds in the near-shore region, the coupling of the seismic and acoustic fields in the earth and atmosphere into the ocean acoustic field, and the propagation characteristics of these sounds within the water column. The engineering objectives are to design signal processing structures, along with arrays of appropriate sensor types, to detect, track, and classify sounds of interest (e.g., breaking surf and land vehicle sounds) in the near-surf-zone environment.

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Adaptive Beach Monitoring

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LONG-TERM GOALS

The long-term goal of the Marine Physical Laboratory's Adaptive Beach Monitoring (ABM) program is to determine the capabilities of small on-shore and off-shore seismoacoustic arrays along with directional wave and current sensors to provide the amphibious force commander with a covert monitoring capability of shore-based as well as near-shore enemy forces, near-shore current and wave dynamics, and beach surf conditions.

OBJECTIVES

The science objectives of the ABM program are to understand the source mechanisms of naturally occurring (e.g., breaking surf and biological) and manmade (e.g., land vehicle) seismoacoustic sounds in the near-shore region, the coupling of the seismic and acoustic fields in the earth and atmosphere into the ocean acoustic field, and the propagation characteristics of these sounds within the water column. The engineering objectives are to design signal processing structures, along with arrays of appropriate sensor types, to detect, track, and classify sounds of interest (e.g., breaking surf and land vehicle sounds) in the near-surf-zone environment.

APPROACH

The approach in the ABM program has been to plan, conduct, and analyze the data from science-oriented experiments in the nearshore region at the Camp Pendleton Marine Base along the Southern California coast. In these nearshore experiments, a large variety of seismoacoustic and environmental data acquisition systems have been deployed, mostly by the Marine Physical Laboratory but also by other organizations (e.g., most recently the offshore array assets in the 1999 Multi-Node Test and the Fleet Evaluation Test deployed by the ADS program). The seismoacoustic systems measured simultaneously the offshore underwater seismoacoustic field, the land seismic field, and the air acoustic field across the 0.05 Hz to 20 kHz band. The ancillary environmental information that were collected included basic weather data, water temperature and salinity, ocean bottom bathymetry, bottom sediment samples for grain size measurements and subbottom profiling, directional ocean surface wave spectra, tide activity, videotapes of surf activity, and ocean currents. Additional ancillary data, e.g., videotapes of beach activity, nearby highway vehicle counts, earthquake origin times and epicentral locations, times of Amtrak train passings, and on-land human activity logs, also were collected.

WORK COMPLETED

Two major nearshore experiments (ABM 95 and ABM 96) have been conducted and the data from both experiments have been fully processed and analyzed. A subsequent echosounding survey and a sediment sampling survey of the site also was carried out in March, 1998, and these data also have been fully analyzed. In addition, land-based data were collected in the Spring of 1999 (ABMjr 99) in conjunction with the ADS program's Multi-Node Test (MNT) and Fleet Evaluation Test (FET) off the Southern California coast. Some results from a preliminary examination of these data are contained in Ref. 1. Efforts last year focused on preparing an Environmental Assessment (EA) to conduct a follow-on experiment. The purpose of this experiment was to examine the effects of offshore bubble advection on low frequency sound propagation in the nearshore environment. Data in the experiment were to be collected with the aid of an AUV. The EA preparation consumed a significant amount of time and effort, and final approval was never obtained due to differences between the Navy environmental activity, N45, and the California Coastal Commission. Delivery of the AUV also

was significantly delayed. These unfortunate circumstances forced a cancellation of the experiment.

The small amount of funds remaining in the program this year were devoted mostly to engineering development of the newly acquired AUV. We also began numerical modeling-based studies of the effects of nearshore bubbles on low frequency propagation.

RESULTS

- Land vehicle activity on the beach can be detected, enumerated, tracked, and possibly classified with bottom hydrophone arrays from at least as far as 3.4 km offshore. At this offshore distance, the beam to background levels approach 20 dB. The signal-to-noise ratio is sufficiently high to permit geoacoustic inversions of the offshore geoacoustic properties using the land vehicle sounds.
- The transits of Amtrak and freight trains along the coast a significant distance inland from the beach are detectable and trackable with underwater acoustic arrays deployed at greater distances offshore than those deployed in the ABM 95 and 96 experiments. The phase velocity of the lower-frequency energy in the offshore arrivals is appreciably greater than the speed of sound in the water column and must be taken into account to avoid biased estimates of the bearings to the trains.
- Low frequency seismic energy on land couples into and propagates as the lowest order mode in the water column. Interface wave energy is insignificant after a distance of 1-2 km outside the surf zone.
- Numerical modeling results indicate that the important geoacoustic parameters dictating the efficiency of coupling of the land seismic field into the offshore underwater field are 1) the rate of increase in water depth with range offshore, 2) the bottom sound speed, and 3) the gradient in bottom sound speed.
- The subbottom profiling results indicate the presence of a sediment-filled river channel in the vicinity of the ABM-96 array location that explains the lack of symmetry about the array location in the seemingly range-independent acoustic source tow data.
- Offshore seismoacoustic arrays used to monitor on-shore activities also can be used to obtain highly resolved directional ocean surface wave spectra.

- Breaking waves introduce bubbles into the water column that have three major effects on the sound field; their initial creation generates sound, their presence attenuates sound (as much as 150 dB/m at 20 kHz), and they drastically lower the effective sound speed in the water column, sometimes to values lower than the speed of sound in air. Once a wave breaks, the water column requires 3-5 min to recover ("de-gas").
- Contribution of surf noise to the offshore ambient noise field during the ABM experiments is very small. One major reason is due to the presence of bubbles in the water column that rapidly attenuate the sound as it passes through the surf zone.
- However, based on data from other locations as well as the ABM site, an empirical model has been developed for surf noise levels as a function of frequency and RMS wave height for a receiver close to the breaker line. At times, the surf noise contribution is significant.
- Sound generation within the surf zone occurs at specific spots ("hot spots") associated with the development and propagation of the active part of the wave breaking which can be tracked with seismoacoustic arrays.
- Modulation of underwater ambient noise levels occurs at diurnal and semidiurnal periods due to the sea breeze effect.
- Inversion of land seismic survey data collected during land detonation events indicate that the near-surface compressional wave velocity is 1.62 km/sec with a 0.71/sec gradient with depth, and the shear wave velocity is 850 m/sec.
- Seafloor inversion of offshore Scholte interface wave data from in-water detonations, with frequency content up to about 10 Hz, gives a shear wave velocity at the interface of 128 m/sec and a gradient of 3.8/sec.
- Just outside the surf zone, increases in surf activity result in higher ambient sound levels at frequencies below 1 kHz, but lower levels in the 4-14 kHz band.
- Land-based cultural sounds such as water and sanitation pumps are clearly detectable by the offshore sensors.
- Biological sounds are the predominant ambient noise source in the underwater acoustic environment outside the surf zone in the 50 Hz to 5 kHz band. Fish choruses raise the nighttime levels by up to 30 dB in a broad frequency band centered around 400-450 Hz and are due to two species of croaker. Individual fish sounds are a series of 5-15 knocks, with the differences in species being associated with differences in the rate of knocking. For both species, the rate of knocking

increased with increases in background chorus level. Inversion of dispersion characteristics of Scholte wave arrivals with frequency content around 50 Hz created by knocking fish at the ocean bottom gives a shear wave velocity of 40 m/sec, in excellent agreement with laboratory measurements of the shear wave velocity in wet sand. These results also are in agreement with the inversions using Scholte wave arrivals from the in-water detonations, given the difference in depth resolution associated with the difference in frequency content of the arrivals used in the inversions.

- Mine drops are detectable over ranges of a few hundred meters by the interface wave created at the ocean/sediment interface upon mine impact on the ocean bottom. Deployment ship noise masks any potential underwater acoustic signal generated during mine entry and descent in the water column.
- Breaking surf often generate seismic interface waves that are measurable by land-based geophones. These "surfseisms" have an arrival structure that is dictated by the character of the wave breaking (plunging versus spilling) and the thickness of the unconsolidated sand layer of the beach, but are completely insensitive to the water column properties (water thickness, bubble content, etc).

IMPACT/APPLICATIONS

Land vehicle and train activity, and other cultural sounds can be detected and tracked/monitored with offshore hydrophone arrays. The array design and signal processing structures to perform this task have been clearly defined. The presence of bubbles in the nearshore region can have a huge impact on sonar systems operating in this environment. Constraints have been placed on type of sensor system and deployment locations to be used for acoustically monitoring surf activity. The demonstrated capability of detecting and tracking acoustic "hot spots" in the surf zone may provide the ability to invert for bottom bathymetry. The offshore seismoacoustic sensor systems, if properly designed, can monitor other important environmental variables such as the directional ocean surface wave spectrum as well as provide surveillance capability.

TRANSITIONS

We have briefed SPAWAR/N87 on the land vehicle tracking results from ABM 95 and ABM 96, coordinated with them and personnel from the SPAWAR Systems Center, San Diego, to collect the on-land data in conjunction with the 1999 MNT and FET experiments, and have participated in their "Hot Wash-Up" and Test Results meetings. A copy of Ref. 1 was included in their Quick-Look Report distributed on CD. These preliminary results were briefed to Tom Higbee, manager of the ADS program, and his staff in February, 2000. Expeditionary Warfare, N85, has been provided material on the ABM program results. We have participated in the annual Expeditionary Warfare Conferences in Panama City, Florida, where we have distributed information on the ABM program results. In addition, we have transitioned some of our ocean engineering expertise gained during the ABM experiments to the responsible FET participants at SPAWAR Systems Center, San Diego and at ARL, University of Texas at Austin.

Several other people and organizations have been briefed on the ABM program, including Adm. Tobin as the Oceanographer of the Navy, Congressman Curt Weldon of Pennsylvania, directors of the Internetted Unattended Ground Sensor program at DARPA, Dr. Paris Genalis who is Deputy Director of the Naval Warfare Office of the Secretary of Defense, and managers of other relevant programs at SPAWAR Systems Center, San Diego.

RELATED PROJECTS

- "Acoustic Attenuation Measurements at Ultrasonic Frequencies", Grant B. Deane
- "Sound Speed Fluctuations in the Surface Wave Zone (ASREX)", W. Kendall Melville
- L. Dorman's studies of seafloor shear velocity in the ONR-sponsored STRATAFORM program, managed by J. Kravitz.
- "Acoustic Measurements and Modeling of the Bubble Distributions in the Surf Zone: Scripps Pier Experiment", W. Kendall Melville
- "Study of Bubble Size Distribution beneath Breaking Waves in the Open Ocean", Grant B. Deane
- "Instrumentation for the Measurement of Bubble Size Distributions in the Ocean Surface Layer", W. Kendall Melville

- "Optical Laser Measurements of Micron Size Bubbles in a Surf Zone", Grant B. Deane
- "Long Time-Scale Ambient Noise Measurements in the Surf Zone", Grant B. Deane
- "T-Phase Excitation and Transfer Function Research", W. A. Kuperman and G. L. D'Spain, examined the reciprocal problem of the coupling of the underwater acoustic field into the land seismic field in support of the monitoring effort for the Comprehensive Test Ban Treaty.

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